Time-Course Analysis of Brain Perfusion Single Photon Emission Computed Tomography Using a Three-Dimensional Stereotactic Region-of-Interest Template in Patients with Moyamoya Disease

Aiki Marushima[1], Hideo Tsurushima[1], Kensuke Suzuki[1,2], Yasunobu Nakai[1], Hirofumi Nemoto[3], Akira Matsumura[1]

Key words
- 3DSRT
- Brain perfusion SPECT
- Cerebral hemodynamics
- Moyamoya disease
- Revascularization surgery

Abbreviations and Acronyms
3DSRT: Three-dimensional stereotactic region-of-interest template
CBF: Cerebral blood flow
CVR: Cerebrovascular reserve
MRI: Magnetic resonance imaging
SPECT: Single photon emission computed tomography
STA-MCA: Superficial temporal artery–middle cerebral artery Tc-99m
Tc-99m ECD: Technetium-99m ethyl cysteinate dimer

From the [1]Department of Neurosurgery, Graduate School of Comprehensive Human Sciences, University of Tsukuba, Tsukuba, Ibaraki; [2]Department of Neurosurgery, Dokkyo Medical University Koshigaya Hospital, Koshigaya, Saitama; and [3]Division of Radiology, Tsukuba University Hospital, Tsukuba, Ibaraki, Japan

To whom correspondence should be addressed: Hideo Tsurushima, M.D., Ph.D. [E-mail: hideo-tsurushima@md.tsukuba.ac.jp]

Citation: World Neurosurg. (2011) 76, 3/4:304-310. DOI: 10.1016/j.wneu.2011.02.004

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

OBJECTIVE: **To verify the usefulness of the time-course analysis of regional cerebral blood flow (CBF) and cerebrovascular reserve (CVR) estimated quantitatively using the three-dimensional stereotactic region-of-interest template (3DSRT) to assess clinical status in patients with moyamoya disease.**

METHODS: **The study comprised 12 patients (5 men and 7 women, age 35.1 years ± 14.7), with 21 hemispheres with the diagnosis of moyamoya disease. During the period 2005–2009, the patients underwent initial and follow-up technetium-99m ethyl cysteinate dimer (Tc-99m ECD) single photon emission computed tomography (SPECT). The 3DSRT was applied to estimate regional CBF at rest and CVR. Time-course changes in CBF and CVR in a region of the middle cerebral artery were analyzed, considering the presence or absence of an ischemic event and revascularization surgery.**

RESULTS: **CBF in hemispheres with ischemic events was significantly lower than CBF in hemispheres without ischemic events based on the initial SPECT study ($P = 0.001$). In 15 hemispheres with a hemodynamic disorder, CBF of the hemispheres in which revascularization was performed was increased significantly after surgery ($P = 0.01$). In contrast, the follow-up CVR of the hemispheres in which revascularization was not performed was decreased significantly compared with the CVR determined in the initial SPECT study ($P = 0.0008$).**

CONCLUSIONS: **Time-course analysis and quantitative SPECT using the 3DSRT were useful for the evaluation of hemodynamic changes involved in disease progression and revascularization surgery in patients with moyamoya disease. Regular hemodynamic studies are important for patients with hemodynamic disorders to determine whether revascularization surgery is indicated to reduce the risk of future stroke.**

INTRODUCTION

Moyamoya disease is a chronic, progressive cerebrovascular disease that is characterized by stenosis or occlusion of the terminal portion of the internal carotid artery. The syndrome involves the proximal portion of the anterior cerebral artery and the middle cerebral artery, with compensatory development of a collateral vascular network known as "moyamoya vessels" (10). Cerebral angiography, magnetic resonance angiography and magnetic resonance imaging (MRI) are usually performed to assist with the diagnosis of moyamoya disease. The angiographic staging of moyamoya disease indicates the progression of the disease, but it does not reflect the clinical severity because the decreased cerebral perfusion caused by steno-occlusion of the circle of Willis can be compensated by the development of moyamoya vessels (5, 10, 16).

The assessment of cerebral hemodynamics is indispensable for decisions regarding treatment strategy, including revascularization surgery. Brain perfusion single photon emission computed tomography (SPECT) is commonly used to assess the cerebral blood flow (CBF) at rest and the cerebrovascular reserve (CVR). The quantitative evaluation of changes in cerebral hemodynamics is important to predict the risk of future stroke in patients with moyamoya disease who present with a chronic and progressive clinical course (2, 3, 5, 8, 9, 11, 15, 16). However, the poor spatial resolution of SPECT images made it difficult to measure regional CBF with high reproducibility. The three-dimensional stereotactic region-of-interest template (3DSRT) is an automated region-of-interest analysis software that is designed to estimate the regional CBF objectively and reproducibly by establishing identical regions of interest on anatomically standardized SPECT images (7, 12–14).

In the present study, CBF and CVR in patients with moyamoya disease were examined during conservative therapy or before and after revascularization surgery using

Table 1. Clinical Characteristics of All Cases

				Angiographic	Ischemic	Hemodynamic	Initial		Follow-up			SPECT
Case	Age (years)	Sex	Side	Stage	Event	Disorder	CBF (mL/100 g/minute)	CVR (mL/100 g/minute)	CBF (mL/100 g/minute)	CVR (mL/100 g/minute)	Revascularization	Interval (months)
1	52	F	Rt	3	—	+	52.5		36.5			47
			Lt	3	+	+	49.9		28.1			47
2	17	M	Lt	1	—	—	49.5	31.4	47.4	15.5		24
3	37	F	Rt	3	—	+	51.3	18.6	52.2	0.5		15
			Lt	4	—	+	43.9	13.5	44.0	−1.6		15
4	33	M	Rt	2	+	+	32.1		27.7			3
			Lt	3	+	+	37.2		45.5		STA-MCA and EDAMS	10
5	20	M	Lt	3	—	+	50.6	13.8	49.5	−1.8		25
6	15	F	Rt	3	—	—	68.5	13.6	49.7	33.6		24
			Lt	3	—	—	60.4	24.1	49.6	29.4		24
7	21	F	Rt	3	+	+	47.4	12.9	56.8	16.9	STA-MCA and EDAMS	21
			Lt	3	+	+	47.0	16.1	56.4	14.0	STA-MCA and EDAMS	21
8	48	M	Rt	3	—	—	54.5		47.4			12
			Lt	3	—	—	54.0		46.2			12
9	55	M	Rt	2	+	+	34.4		42.7		STA-MCA and EDAMS	17
			Lt	2	+	+	42.5		38.7			13
10	51	F	Rt	3	+	+	42.7	−8.7	47.4	3.6	STA-MCA and EDAMS	3
11	43	F	Rt	2	—	—	48.4		53.5			13
			Lt	3	+	+	45.7		52.6		STA-MCA and ESS	13
12	29	F	Rt	3	—	+	45.1		54.1			16
			Lt	3	+	+	41.9		51.9		STA-MCA and EDAMS	16
	35.1	M/F										18.6
	±14.7	=5/7										±11.3

CBF, cerebral blood flow; CVR, cerebrovascular reserve; EDAMS, encephaloduroarteriomyosynangiosis; ESS, encephalosubgaleosynangiosis; Lt, left; SPECT, single photon emission computed tomography; STA-MCA, superficial temporal artery–middle cerebral artery anastomosis; Rt, right.

technetium-99m ethyl cysteinate dimer (Tc-99m ECD) SPECT. We verified the usefulness of the time-course analysis of regional CBF and CVR estimated quantitatively using the 3DSRT to assess clinical status in patients with moyamoya disease.

METHODS

Study Patients

The study comprised 12 patients (5 men and 7 women), with 21 hemispheres with the diagnosis of moyamoya disease. The patients underwent initial and follow-up Tc-99m ECD SPECT during the period 2005–2009 at our institution (**Table 1**). The median age at the initial SPECT study was 35.1 years ± 14.7 (range 15–55 years). Clinical diagnosis of moyamoya disease was accomplished using criteria prepared by the Research Committee on Spontaneous Occlusion of the Circle of Willis (moyamoya disease) in Japan. Both definite and probable cases were included in this study (1, 4). Pediatric patients <14 years of age, patients with hemorrhagic types of moyamoya disease, and hemispheres in which revascularization surgery was performed before this study were excluded.

The cerebral hemispheres were divided into 11 hemispheres without ischemic events and 10 hemispheres with ischemic events based on the clinical symptoms and the neuroradiologic findings, including MRI, angiography, and initial cerebral perfusion SPECT. The ischemic events in-